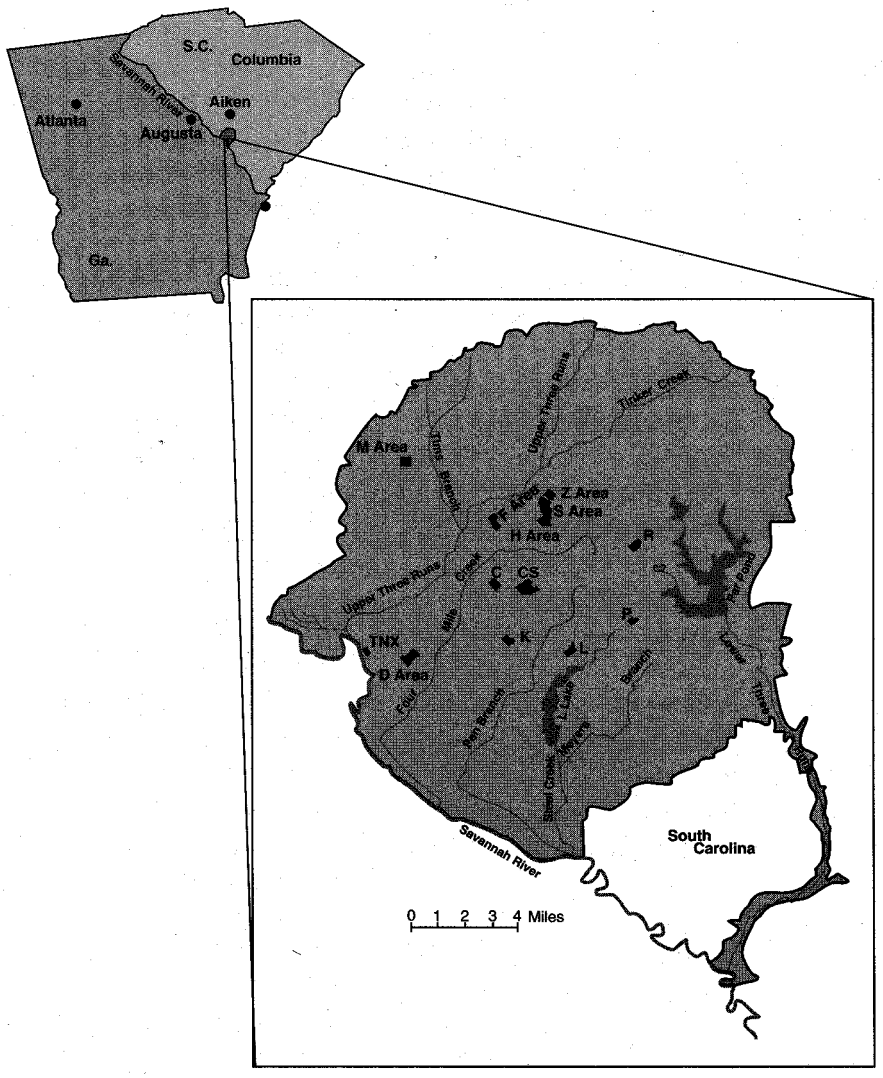
Savannah River Site

e fact sheet

Glossary of Dose Reconstruction Terms

These definitions are presented to help individuals interested in the Savannah River Site Dose Reconstruction Project deal with terms used in reports, fact sheets, newsletters, and presentations. The Centers for Disease Control and Prevention and *Radiological Assessments Corporation* welcome suggestions to improve this glossary. Please mail suggestions to: Dr. John E. Till, 417 Till Road, Neeses, SC 29107, or comment by calling 800-637-4766. (Note that *italicized* words below are defined separately in this glossary.)

Savannah River Site (SRS): One of several government facilities involved in the production of nuclear materials. The SRS was built in the early 1950's, and produced much of the *plutonium* and *tritium* used in U.S. nuclear weapons.



The 300-square-mile Savannah River Site contains a central ring of five reactors and two reprocessing plants spaced well apart and away from the site boundary. The reactors produced plutonium, tritium, and other radionuclides; the reprocessing facilities dissolved and separated these materials for use elsewhere, producing radioactive and chemical waste in the process. Creeks and ponds onsite drain into the Savannah River. Some radionuclides and chemicals released during reprocessing moved into these waters or were disposed of onsite; some of these materials continue to be released to the Savannah River.

Absorbed dose (measures potential damage to tissue)**:** The amount of energy deposited by ionizing radiation in a unit mass of tissue. Expressed in units of joule per kilogram (J/kg), which is given the special name "gray" (Gy). The traditional unit of absorbed dose is the *rad* (100 rad equal 1 Gy).

Alpha particle (ionizing radiation)**:** A particle emitted from the nucleus of some radioactive atoms when they decay. An alpha particle is essentially a helium atom nucleus. It carries much more energy than gamma or beta radiation, and deposits that energy very quickly while passing through tissue. Alpha particles cannot penetrate the outer, dead layer of skin. Therefore, they do not cause damage to living tissue when outside the body. When inhaled or ingested, however, alpha particles are the most damaging of the common radiations, because they transfer relatively large amounts of ionizing energy to living cells in the lung or other organs. Plutonium-239 emits alpha particles.

Becquerel (Bq) (a measure of the rate of radioactive decay)**:** The Bq corresponds to one decay (disintegration) per second. The traditional unit of activity is the *Curie* (Ci).

Beta particle (ionizing radiation): An electron ejected from the nucleus of a decaying atom. Energetic beta particles penetrate the dead skin layer. The beta particle is not stopped in tissue as quickly as an alpha particle, producing less damage per living cell. Beta particles may interact with living tissue from both outside and inside the body.

Centers for Disease Control and Prevention (CDC): The CDC sponsors the Savannah River Site Environmental Dose Reconstruction Project, and similar projects in Ohio, Idaho and elsewhere.

Confinement: Describes the equipment that confines radioactive material to prevent it from being released from a facility such as a reactor into the outside environment. Contamination is confined by directing it into ventilation system filters, sumps, or holding tanks. SRS reactors do not produce the higher temperatures and pressures of commercial power reactors; therefore they use confinement rather than *containment*.

Containment: Defines the structures that prevent the escape of radioactivity from commercial nuclear power reactors. Commercial reactor containment structures usually include thick layers of concrete reinforced with steel.

Control rods: Rods made of neutron-absorbing material that are moved in and out of a nuclear reactor core to control the fission process.

Coolant: A substance circulated though the core of a nuclear reactor to remove or transfer heat. The most common coolants are water, and heavy water. SRS production reactors used heavy water, containing the hydrogen isotope deuterium, as coolant. Heavy water also moderates, or slows, the neutrons moving through a reactor, greatly increasing the efficiency of reactor operation.

Core: The central portion of a nuclear reactor containing fuel, *control rods*, *coolant*, *moderator*, and target assemblies. Nuclear fission takes place within the reactor core, releasing heat and radiation and creating radioactive isotopes. The term *core* may also mean the central portion of a nuclear weapon, containing highly enriched uranium or plutonium.

Criticality: The condition in which a self-sustaining nuclear chain reaction is achieved. In a reactor, fission is controlled closely to limit the energy produced. In a nuclear weapon, conditions are created to maximize the number of fissions that occur in a short time to release the maximum energy.

Cumulative dose: The total dose resulting from the intake of radioactive material into

the body. When plutonium is ingested or inhaled, it remains in the body for a long period, and continues to emit radiation. Therefore, the radiation dose from such plutonium continues to increase over many years. The cumulative dose is the total dose for that period. For short-lived radionuclides, or for radionuclides such as tritium that do not remain in the body for long periods, the dose accumulates over only a short period. For short exposure to gamma or beta radiation from a source outside the body, the radiation dose occurs only during the actual exposure period; there is no cumulative dose.

Curie (Ci) (a measure of the rate of radioactive decay)**:** The traditional decay unit. Given the same number of atoms of two different radioactive materials, the more radioactive material decays more quickly, emits more radiation per second, and contains more curies of radioactivity. The curie is a very large unit, representing 3.7 x 10^{10} (37,000,000,000) disintegrations per second. The new international unit of activity is the Becquerel (Bq), which corresponds to 1 disintegration per second, or 2.7 x 10^{-11} curies. Environmental levels from routine releases of radioactivity are typically of the order of Becquerels, or picocuries (pCi) (10^{-12} Ci, or 0.037 disintegrations per second). Power reactor core radioactivity levels are typically many millions of curies.

Deuterium (^{2}H or D): A natural isotope of hydrogen, heavier than ordinary hydrogen because it contains a neutron in addition to the proton in its nucleus. When two deuterium atoms combine with an oxygen atom, the water molecule formed is called heavy water. Heavy water was used to cool and moderate Savannah River Site reactors, because deuterium is effective in slowing neutrons, increasing the number of fission reactions.

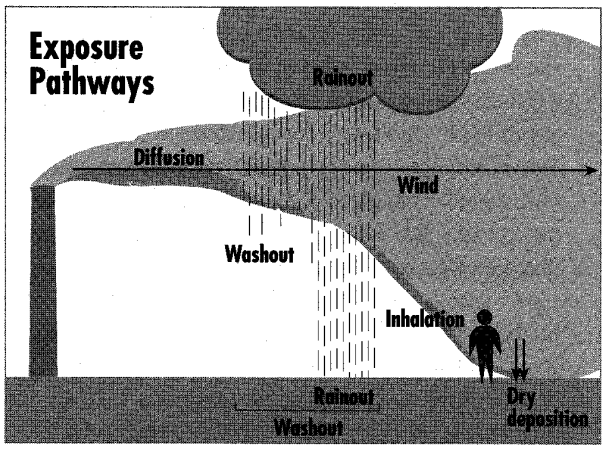
Dose: A term denoting the amount of energy imparted to tissue during interaction with ionizing radiation. Ions and free radicals created inside living cells can cause damage to key materials such as cell DNA, sometimes leading to cancer or other health effects. The gray (Gy) or rad are units used to measure absorbed radiation dose. Doses to individuals exposed to environmental radiation are typically measured in thousandths of gray, or milligray (mGy). At these doses, no effects in humans have been seen. Higher doses, of the order of a gray, can produce measurable immediate and long-term health effects.

Dosimetry: Dosimetry involves methods developed over the years to measure the radiation doses to humans exposed to ionizing radiation. Such methods may range, for examples, from sensitive badges worn by the people potentially exposed to radiation, to external gamma radiation measurements taken by hand held counting devices, to chemical and radionuclide analyses of urine samples to determine the amount of intake of radionuclides such as tritium or plutonium.

Emergency Core Cooling System (ECCS): An emergency safety system that provides additional cooling water to a fission reactor to prevent reactor core melting if normal coolant flow is lost. Because fission reactors contain large quantities of rapidly decaying fission products (radioactive isotopes with very short half-lives, producing large quantities of decay heat for a short period after an emergency reactor shutdown), the reactor fuel must be cooled even after shutdown. If normal cooling systems have failed because of an accident, the ECCS provides cooling water to prevent heat and temperature from increasing to the melting point of the fuel and structures.

Equivalent dose: A quantity used in radiation protection to place all radiation on a common scale for calculating tissue damage. Equivalent dose is the product of the absorbed dose in grays and the radiation weighting factor (wR). The radiation weighting factor accounts for differences in radiation effects caused by different ionizing

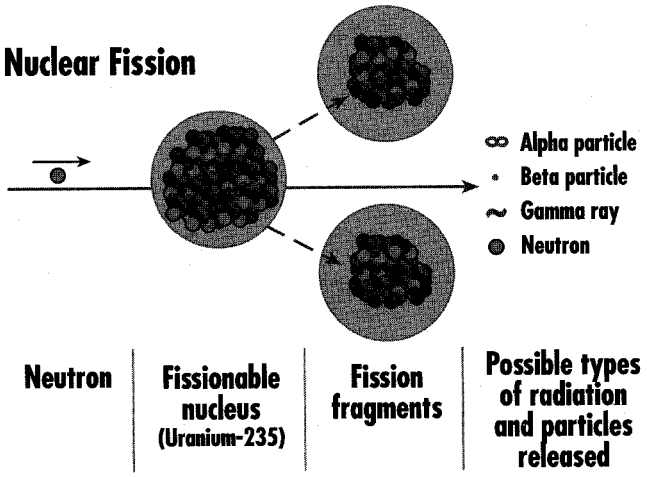
radiations. Some radiations, including alpha particles, cause a greater amount of damage per unit absorbed dose than other radiations. This is, in part, because they release energy over shorter distances in tissue, making biological repair processes less effective. The sievert (Sv) is the unit used to measure equivalent dose. The sievert replaces the



rem, the traditional unit (1 Sv equals 100 rem).

Exposure pathways: The means by which humans are exposed to toxic substances. The key exposure pathways are air and water, with most exposures via inhalation, drinking water, crops, other foods and direct radiation.

Fission: When certain heavy atoms, most importantly uranium 233,235 and plutonium 239, interact with neutrons, they may split, or fission, releasing radiation, heat and neutrons, and creating radioactive materials.



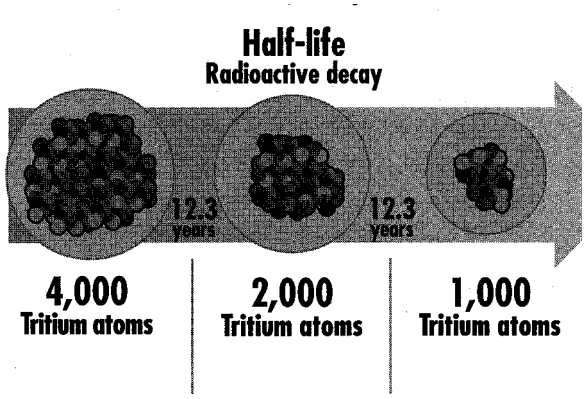
Gamma radiation (ionizing radiation): High energy electromagnetic radiation emitted from a decaying atomic nucleus. Gamma rays are similar to medical x-rays, but are emitted at very specific energies characteristic of their decaying atoms. They penetrate tissue more effectively than beta or alpha particles, leaving ions in their path to potentially cause cell damage. Gamma rays travel relatively long distances in air, and leave a low density of ionization damage in their track through tissue. Gamma-emitting radionuclides are hazards from outside the body because their radiation penetrates to living tissue, but they are of less concern than alpha-emitters when ingested or inhaled, because their ionizing energy is deposited less effectively in tissue.

Gray (Gy): The unit of absorbed dose that replaces the traditional unit, the rad (1 Gy equals 100 rad).

Half-life, biological: The time required for the body to eliminate one-half of any absorbed substance via its regular processes. Generally the same for both stable and radioactive isotopes of a particular element. Sometimes referred to as *half-time.*

Half-life, effective: The time required for a radioactive element in an animal or a human body to be reduced by one-half as a result of the combined action of *radioactive decay* and *biological elimination*.

Half-life, radioactive: The time required for half the atoms of a radioactive substance to disintegrate. During one half-life, the number of radioactive atoms in a material is reduced by one-half. Each radionuclide has a unique half-life. Tritium decays with a half-life of 12.3 years, and plutonium-239 decays with a half-life of 25,000 years.



Health Physics: Health Physics is an interdisciplinary science focused on the radiation protection of humans and the environment. Health Physics combines the elements of physics, biology, chemistry, statistics, and electronic instrumentation to protect individuals from the effects of radiation.

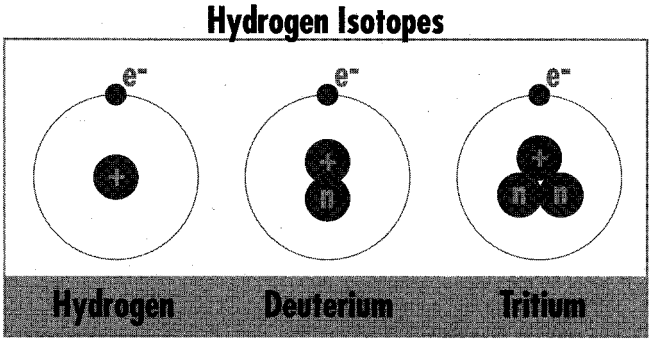
Ingestion: Radionuclides or chemicals taken into the body by eating or drinking are taken in by ingestion.

Inhalation: Radionuclides or chemicals taken into the body by breathing are inhaled.

Iodine (I): An element used by the thyroid gland to produce hormones that control metabolism. The thyroid constitutes about 0.5% of the mass of the human body, but holds 25% of the body's iodine. The thyroid is thus sensitive to damage from inhaled or ingested radioactive isotopes of iodine.

Ionizing radiation: Ionizing radiation has enough energy to create ions (ionized atoms, which are chemically active) inside living cells. These ions can damage key substances in cells, including the DNA containing the record of the cell's characteristics. Such damage can lead to cancer or other defects.

Isotopes: Atoms of the same element, containing the same atomic number of protons but a different number of neutrons. Different isotopes of a particular element generally have essentially identical chemical properties. Hydrogen, deuterium, and tritium are all isotopes of the element hydrogen.



Lithium (Li): A soft, silvery-white element; the lightest metal. It was used as a target material to produce tritium in Savannah River Site reactors.

Loss-of-coolant accident (LOCA): An accident that results in the loss, by catastrophic leakage, of normal coolant flow in a fission reactor. If the reactor is running at high power, such loss of coolant can lead to core heating and melting if emergency coolant is not supplied.

Maximum contaminant level (MCL): A standard for drinking water established by the U.S. Environmental Protection Agency under the Safe Drinking Water Act. It is the permissible level of a chemical in the water delivered to any user of a public water system.

Millirem (mrem): One-thousandth of the traditional measure of radiation dose that takes into account the effects of radiation on humans (1 rem equals 1000 mrem; 100 mrem equal 1 mGy).

Millisievert (mSv): One-thousandth of the current measure of radiation dose that takes into account the effects of radiation on humans (1000 mSv equals 1 sievert; 100 mrem equals 1 mSv).

Modeling: When determining the risks to humans from past operations of a plant such as the Savannah River Site, it is rare to find actual measurements of offsite dose. In such cases, doses from past releases must be estimated using models. For example, models are used to simulate environmental movements of radionuclides and chemicals released from a facility's stacks. Models calculate how materials disperse as they move with the winds, how they deposit on food crops, how they are inhaled or ingested by people, and the resulting doses. Some models are complex, requiring information such as weather conditions, crops, and eating habits. Other models are relatively simple.

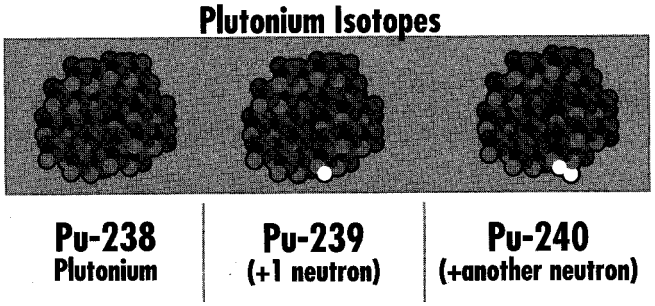
Moderator: A component (usually water, heavy water, or graphite) used in nuclear reactors to slow neutrons, making them more effective in producing fission events within the core.

National Ambient Air Quality Standards (NAAQS): Health-based standards for outside air, established by the U.S. Environmental Protection Agency under the Clean Air Act. To date, NAAQS have been established for carbon monoxide, lead, nitrogen dioxide, particulate matter less than 10 microns in size, ozone, and sulfur dioxide.

National Council on Radiation Protection and Measurements (NCRP): The NCRP produces recommendations concerning all aspects of radiation protection, including many reports defining recommended methods for performing key aspects of dose reconstruction.

Plume: The concentration profile of an airborne or waterborne release of material as it spreads from its source. A plume from a coal-fired power plant, for example, may be visible for some distance from its stack, with the concentration of its components decreasing with distance from the stack and from the centerline of the plume. After the plume becomes invisible because of dilution, it continues to be diluted with increasing time and distance. Atmospheric dispersion models of this process predict concentrations within a plume far downwind and far beyond the point at which a plume becomes invisible. Similar modeling for releases from nuclear facilities can estimate the impacts of releases long past, reconstructing exposure and dose estimates.

Plutonium (Pu): A silvery-white radioactive metal that exists as a solid under normal conditions. Plutonium-239 (Pu-239) does not occur in nature; it is produced when uranium absorbs neutrons during exposure in a reactor. Pu-239 is the critical element of many nuclear weapons. Plutonium is a key weapons material that was produced at the Savannah River Site.



Production reactor: A nuclear reactor designed primarily for large-scale production of special nuclear materials such as Pu-239 for defense purposes. Production reactors may also produce other radionuclides for medical, research, energy or other purposes.

Rad: The traditional unit of absorbed dose equal to 100 ergs/gram in any medium; now replaced by the gray (1 gray equals 100 rad).

Radiation: Energy moving in the form of particles or waves. Familiar radiations are heat, light, radio waves and microwaves. Ionizing radiation is a very high frequency form of electromagnetic radiation. It is invisible and cannot be sensed without the use of detecting equipment. Ionizing

radiation creates ionizations within tissue; these ions can cause cell damage.

Radioactive contamination: *Radioactive material* distributed over an area, equipment or an individual.

Radioactive material: Contains unstable (radioactive) atoms that generally give off radiation as they decay. Radioactive materials produce radiation when they decay.

Radioactivity: Spontaneous transformation of an unstable atom, often resulting in the emission of radiation. This process is referred to as decay or disintegration of an atom.

Radiological: Related to radioactive materials or radiation. The radiological sciences focus on the measurement and effects of radiation.

Radionuclide: A radioactive isotope, for example, plutonium-239 or tritium. Plutonium-239 emits alpha particle radiation when it decays; tritium emits low-energy beta particles.

Reactor: A large vessel that contains uranium or plutonium fissionable fuel, water or other coolant; moderator to slow neutrons, control rods to allow operators to control the number of neutrons available to produce nuclear fission; and structures that support the fuel, rods, and other components and transport the coolant.

Receptors: Persons, waters, food plants or animals potentially affected by a release of a hazardous material.

Reference Concentration (RfC): A toxicity value for evaluating potential noncarcinogenic effects resulting from exposure to chemicals. An estimate of inhaled daily exposure that may be without appreciable risk of adverse effects over a lifetime.

Reference Dose (RfD): A toxicity value for evaluating potential noncarcinogenic effects resulting from exposure to chemicals. An estimate of ingested or oral daily exposure that is likely to have no appreciable risk of adverse effects over a lifetime.

Rem: Acronym of (roentgen equivalent [to] man). The traditional unit of equivalent dose; replaced by the sievert (Sv) (1 Sv = 100 rem).

SCRAM: A rapid shutdown of a nuclear reactor accomplished by moving the neutron-absorbing control rods into the reactor core to halt the chain reaction.

Sievert (Sv): The unit of radiation equivalent dose of any ionizing radiation that produces the same biological effect as a unit of absorbed dose of ordinary x-rays (1 sievert = 100 rem).

Slope factor: A toxicity value for evaluating potential carcinogenic effects resulting from exposure to chemicals. An upper bound estimate of the lifetime cancer risk per unit of exposure.

Source term: The quantity of radioactive material or chemical released from identified sources or from incidents at a facility. It is usually specified as a rate (quantity released over time, such as, Becquerels per second).

Tritium (^{3}H, H-3 or T): A radioactive isotope of hydrogen containing a nucleus of two neutrons and one proton. Tritium has a half-life of 12.3 years. It is used to multiply the firepower of nuclear weapons.

Uncertainty analysis: A determination of the upper and lower bounds of the margin of error associated with a source term, environmental concentration, dose, or risk estimate.

Uranium (U): The heaviest natural element. Uranium-235, one of the uranium isotopes, can be made to fission through the capture of

neutrons. Neutrons produced during fission can in turn fission other U-235 atoms, leading to a chain reaction under certain conditions.

U.S. Department of Energy (DOE): The DOE is responsible for developing and producing nuclear weapons and for the sites at which weapons materials have been produced or handled. Generally, private organizations, such as DuPont and Westinghouse, have operated the weapons facilities for the DOE.

U.S. Environmental Protection Agency (EPA): The EPA establishes standards limiting the radiation exposures allowed for individuals living near facilities releasing radiation or radioactive materials.

U.S. Environmental Protection Agency Cancer Group Designations:

Group A Carcinogen: Human Carcinogen. Sufficient human epidemiological evidence exists to demonstrate that the chemical causes cancer in humans. The U.S. Environmental Protection Agency classifies all radionuclides as Group A carcinogens.

Group B Carcinogen: Probable Human Carcinogen. B1 - There is limited evidence in human studies to demonstrate that the chemical causes cancer in humans. B2 -There is sufficient evidence in animal studies "with inadequate or lack of evidence in human studies" to demonstrate that the chemical causes cancer in humans.

Group C Carcinogen: Possible Human Carcinogen. There is limited evidence in animals and inadequate or lack of human studies to demonstrate that the chemical causes cancer in humans.